



ELSEVIER

Preventive Veterinary Medicine 44 (2000) 97–106

PREVENTIVE
VETERINARY
MEDICINE

www.elsevier.nl/locate/prevetmed

Risk factors for high herd level calf morbidity risk from birth to weaning in beef herds in the USA

M.W. Sanderson^{a,*}, D.A. Dargatz^b

^a*Department of Clinical Sciences, Kansas State University, Veterinary Medical Teaching Hospital,
1800 Denison Avenue, Manhattan, KS 66506, USA*

^b*Centers for Epidemiology and Animal Health, USDA — Animal Plant Health Inspection Service — Veterinary
Services, Ft Collins, CO 80521, USA*

Received 19 January 1999; accepted 11 November 1999

Abstract

We analyzed data from a national survey of beef cow–calf producers in the USA to quantify the effects of hypothesized risk factors on herd-level calf morbidity risk from birth to weaning. The analysis included 2490 herds from 23 states. Two stepwise logistic regressions were fit to identify factors associated with $\geq 10\%$ morbidity. The first model included all herds dichotomized into high-morbidity herds with $\geq 10\%$ morbidity and low-morbidity herds with $< 10\%$ morbidity. The second model excluded herds with between 5 and 10% morbidity, and compared $\geq 10\%$ morbidity with $\leq 5\%$ morbidity. The risk of dystocia was categorized into five levels for analysis; all non-zero categories were associated with increased odds of being a high-morbidity herd compared to herds with no dystocia (OR=2.7–5.5). Having $> 70\%$ of cows and heifers calves in confinement also increased the odds of being a high-morbidity herd (OR=1.8). The population attributable fractions for dystocia and confined calving for the model including all herds dichotomized at 10% morbidity were 0.41 and 0.11, respectively. The summary population attributable fraction for both factors was 0.46. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Cow–calf; Calf-health; Morbidity; Logistic regression; Risk factors

1. Introduction

Although there is extensive literature on beef-calf mortality and the associated risks (Kasari and Wikse, 1994), there has been only limited research on beef-calf morbidity.

* Corresponding author. Tel.: +1-785-532-5700; fax: +1-785-532-4309.

E-mail address: sandersn@vet.ksu.edu (M.W. Sanderson).

This scarcity of published literature may be related to difficulty in validating case definitions for morbidity incidents and collecting the records necessary to calculate specific morbidity risk and incidence densities. Wittum et al. (1994a) examined individual-animal risk factors for morbidity and mortality from birth to 45 days of age in 10 beef cow–calf herds. They found increased incidence of general morbidity among calves born to 2 year-old heifers and to calves experiencing dystocia. In a separate analysis (Wittum et al., 1994b), they showed a 15.9 kg reduction in calf weaning weight among calves experiencing general morbidity from birth to 45 days of age. Wittum and Perino (1995) replicated this result; they showed a 16 kg reduction in weaning weight among calves experiencing a morbidity incident between birth to 28 days of age. Salman et al. (1991a,b) estimated the incidence of calf morbidity and the costs associated with its occurrence in CO, USA beef herds. Diarrhea of unknown cause (predominately in calves) had the highest costs associated with treatment and labor of all disease categories. Additionally, >75% of annual miscellaneous costs of disease was due to lost weight gain. The purpose of this study was to quantify the effect of herd management and event variables on herd risk for high calf morbidity.

2. Materials and methods

2.1. Data source

A stratified random sample of 4092 operations expected to have beef cows was selected from 23 states¹ by the USDA: National Agricultural Statistics Service (NASS) from its list frame of all census-identified farm operations in the USA. NASS enumerators attempted to contact all of the selected operations for a personal interview regarding management practices. Non-institutional operations with one or more beef cows were eligible to participate in the study. Institutional herds (such as those operated by universities, governmental agencies or prisons) were excluded from the study. Additional reasons for exclusion included: zero beef cows on hand (298 operations), out of business (79 operations), inaccessible (231 operations), out of scope (six operations) and refused (760 operations). Of eligible operations, 73.2% responded (2713/3704). For operations that met the inclusion criteria for the study and were willing to participate, the enumerators administered a questionnaire. All questionnaires were administered between 30 December 1996 and 3 February 1997. Survey questions referred to management practices and event variables during the calendar year 1996. The questionnaire was pilot tested on operations throughout the USA prior to the initiation of the survey. In addition, the questionnaire underwent extensive review by a panel of experts familiar with beef cow–calf production. Questionnaire data were collected from 2713 operations. Population estimates were calculated according to standard techniques by weighting the data according to the sampling design and non-response rate to obtain unbiased population estimates (Dargatz and Hill, 1996). Population estimates were published

¹ The states of AL, AR, CA, CO, FL, GA, IL, IA, KS, KY, MT, MS, MO, NE, NM, ND, OK, OR, SD, TX, TN, VA, and WY.

previously (USDA:APHIS:VS, 1997a,b). The reference population for the study reported here includes 77.6% of the operations with beef cows in the United States and 85.7% of the beef cows in the United States. From this random sample, a subset of 2490 herds was identified that had complete records (92% of the 2713 herds).

Participating producers were asked to estimate the number of calves experiencing morbidity from respiratory disease, diarrhea (also called “scours”), bovine keratoconjunctivitis (also called “pinkeye”) and infectious pododermatitis (also called “footrot”) from birth to 3 weeks of age and from >3 weeks of age to weaning. Producers were also asked to estimate the number of dystocias in heifers and cows during 1996. Calvings were reported as “easy pulls”, “hard pulls”, “Cesarean sections”, or “no assistance given”. Producers also provided estimates of the percent of cows and heifers calved in confined and extensive facilities. Extensive calving facilities were defined as calving at range or pasture without access to pens or lots. Confined calving was defined as the proportion of cows calving in pens, sheds, or lots without access to grazing. Producers also reported the number or percent of calves born in each month of the year.

2.2. Data analysis

The analytic unit was the herd, and the outcome for all models was high vs low herd-level calf morbidity. A single morbidity risk was calculated for each herd by adding the estimates in each morbidity category from birth to weaning for the year 1996, and dividing by the total number of live-born calves in the herd during 1996. This calculated calf morbidity value for the herd was used to categorize herds into high- and low-morbidity herds. Initially, high-morbidity herds were defined as herds with $\geq 10\%$ morbidity. Low-morbidity herds were defined as herds with $< 10\%$ morbidity. This variable was used as the outcome variable for the first multiple logistic-regression model. To assess the effect of imprecision in morbidity risk for operations around the 10% cutpoint, a second logistic regression was run excluding all operations with morbidity risk between 5 and 10%.

Herd dystocia risk was calculated by summing the estimates for easy pulls, hard pulls and cesarean sections divided by the number of calves born alive or dead. The combined dystocia risk for cows and heifers was categorized into five levels using four design variables. The categories created were no dystocia for the reference group, >0 to 5% dystocia, >5 to 10% dystocia, >10 to 20% dystocia and >20% dystocia. Whether or not cows were regularly observed during calving season was also reported and examined in the model.

The estimate of percent of cows and heifers calved in confined facilities was categorized into three categories using two design variables. The categories created for calving confinement were $\leq 20\%$ for the reference group, >20 to 70%, and >70% calved in confinement.

Herds were categorized into three groups based on the predominant season of calving to compare predominantly winter calving to predominantly summer calving. Herds that calved $\geq 70\%$ of calves from November to April were compared to herds that calved $\geq 70\%$ of calves from May to October, and herds that did not calve $\geq 70\%$ of calves in either period.

The state of residence for the herd was grouped based on geographic regions of the country with similar climate and management practices. Regions were Southeast (the states of AL, FL, GA, KY, MS, TN, and VA), Central (the states of AR, IL, IA, and MO), South-central (the states of OK and TX), North-central (the states of KS, NE, ND, and SD), and West (the states of CA, CO, MT, NM, OR, and WY).

Based on biological plausibility, all potential explanatory variables for which data were present for all herds were examined for univariable association with calf morbidity. Variables associated with the outcome ($p \leq 0.25$) were included in an initial multiple logistic-regression model (Hosmer and Lemeshow, 1989). Variables in the initial model were screened for inclusion by backward elimination using SUDAAN (Shah et al., 1996) to account for the sampling design as described previously (Dargatz and Hill, 1996). Potential explanatory variables were manually eliminated from the model one at a time based on the largest p value for the Wald statistic in SUDAAN, which is adjusted to account for stratification and clustering. (This approach was used because weighted and design-adjusted log-likelihood values are not available in this survey-analysis procedure.) When all remaining variables in the model had a Wald statistic p value ≤ 0.05 , no further variables were removed. No estimate of goodness-of-fit is available for the weighted design based analysis from SUDAAN. Therefore, final model fit of the models was assessed for the sample data, unweighted and without incorporating the design, using the Hosmer Lemeshow goodness-of-fit statistic (Hosmer and Lemeshow, 1989) and by visual evaluation of residual plots using the Statistical Analysis System (Proc Logistic; SAS, 1990). Population attributable fractions (PAFs) were calculated for the risk factors identified by the multiple logistic model according to the multivariable methodology previously described (Bruzzi et al., 1985). The formula used was

$$\text{PAF} = 1 - \sum_j \left(\frac{p_j}{R_j} \right)$$

where p_j is the proportion of high-morbidity herds in stratum j and R_j is the multivariable odds ratio for stratum j . Confidence limits for the population attributable fraction were calculated using the upper and lower 90% confidence limits for the estimated odds ratio as described previously (Wells et al., 1996). The summary population attributable fraction was calculated using the above equation and summing across all strata where p_j is the proportion of high-morbidity herds in each cross-classified stratum and R_j is the odds ratio for each cross-classified stratum.

3. Results

Overall, 2490 herds were identified with complete questionnaire data. A surprising number (54%) of the herds reported calving only cows and no heifers. Because of the low number of herds that calved heifers, inclusion of specific risk factors associated with heifers affected sample size substantially and were not included. The weighted estimate of mean morbidity prior to weaning was 5.8%, and weighted mean mortality risk prior to weaning was 3.7%. Table 1 gives population estimates of the percent of operations with

Table 1

Percent of operations with ≥ 10 and $\leq 5\%$ morbidity from birth to weaning in 1996^a

Variable/response	Operations with $\geq 10\%$ morbidity		Operations with $\leq 5\%$ morbidity	
	Percent	Standard error	Percent	Standard error
Overall	18.9	0.8	79.3	0.9
Region [*]				
Southeast ^b	18.3	2.7	77.7	2.8
Central ^c	22.8	2.8	65.5	3.5
South-central ^d	8.1	1.6	85.8	2.4
North-central ^e	36.7	3.5	49.7	3.5
West ^f	21.8	3.9	60.0	4.6
Percent calved in confinement [*]				
$\leq 20\%$	16.1	1.2	76.3	1.5
>20 to $\leq 70\%$	37.2	8.9	41.6	7.3
$>70\%$	38.6	4.2	47.8	4.6
Percent dystocia [*]				
0%	11.3	1.4	83.6	1.5
>0 to $\leq 5\%$	28.3	2.7	56.8	2.8
>5 to $\leq 10\%$	30.2	3.6	54.7	4.2
>10 to $\leq 20\%$	35.6	6.2	47.0	6.6
$>20\%$	46.0	10.5	49.9	10.5
Predominant calving season				
$\geq 70\%$ November–April	20.2	1.7	70.4	1.9
$\geq 70\%$ May–October	15.0	3.7	80.0	4.2
No defined season	17.4	2.3	74.4	2.9
Import unweaned calves				
Yes	23.6	5.4	61.2	8.3
No	18.6	1.3	73.2	1.4
Observe cows regularly during calving season [*]				
Yes	27.0	2.4	60.8	2.7
No	16.0	1.5	76.6	1.8

^{*} Associated with morbidity risk, $p < 0.25$.^a Variables associated with morbidity risk ($p < 0.25$) were offered to the multivariable logistic model.^b The states of AL, FL, GA, KY, MS, TN, and VA.^c The states of AR, IL, IA, and MO.^d The states of OK and TX.^e The states of KS, NE, ND, and SD.^f The states of CA, CO, MT, NM, OR, and WY.

$\geq 10\%$ morbidity and $\leq 5\%$ morbidity by management practice. Table 2 gives population estimates of means of continuous variables for operations with ≥ 10 , < 10 , and $\leq 5\%$ morbidity.

The predominant season of calving, the interaction of region and predominant calving season and the effect of importing young calves onto the operation were not associated with high herd-level calf morbidity in univariable screening ($p > 0.25$) and were not offered to the logistic model.

Table 2

Mean values of continuous variables in operations with $\geq 10\%$ and $\leq 5\%$ morbidity from birth to weaning in 1996^a

Variable/response	Operations with $\geq 10\%$ morbidity		Operations with $< 10\%$ morbidity		Operations with $\leq 5\%$ morbidity	
	Mean	Standard error	Mean	Standard error	Mean	Standard error
Herd size [*]	56.5	3.3	49.8	2.2	44.7	2.3
Percent dystocia in cows [*]	5.7	1.0	2.2	0.3	2.0	0.1
Percent hard dystocia in cows [*]	1.6	0.5	0.7	0.1	0.7	0.1
Percent heifers in the herd [*]	7.6	1.0	8.0	1.0	8.1	1.0

^{*} Associated with morbidity risk, $p < 0.25$

^a Variables associated with mortality risk ($p < 0.25$) were offered to the multivariable logistic model.

Table 3

Results of backward logistic regression (using SUDAAN) to identify factors associated with $\geq 10\%$ morbidity (Model 1)^a

Variable	SUDAAN Model 1		SUDAAN Model 2	
	Odds ratio	95% CI	Odds ratio	95% CI
Constant	0.15	0.1–0.2	0.15	0.1–0.2
Region				
Southeast ^b	1		1	
Central ^c	1.0	0.7–1.6	1.2	0.8–1.8
South-central ^d	0.4 ^{***}	0.2–0.7	0.4 ^{**}	0.2–0.7
North-central ^c	1.5	0.9–2.4	1.7	0.9–2.8
West ^f	0.8	0.4–1.6	1.0	0.5–2.0
Dystocia class				
0%	1		1	
>0 to 5%	2.7 ^{***}	1.8–4.0	3.1 ^{**}	2.1–4.7
>5 to 10%	2.7 ^{***}	1.7–4.2	3.0 ^{**}	1.9–4.7
>10 to 20%	3.2 ^{***}	1.8–5.8	4.1 ^{**}	2.2–7.5
>20%	5.5 ^{***}	2.3–13.1	5.2 ^{**}	2.1–12.7
Confined calving				
0 to 20%	1		1	
>20 to 70%	1.3	0.7–2.7	1.8	0.9–3.8
>70%	1.8 ^{**}	1.2–2.8	2.0	1.2–3.2

^{**} $p < 0.01$.

^{***} $p < 0.001$.

^a A second model was run to verify parameter estimates using herds with $\geq 10\%$ or $\leq 5\%$ morbidity (herds with morbidity $> 5\%$ and $< 10\%$ were excluded, Model 2). The logistic regression model was run in SUDAAN to obtain unbiased population estimates.

^b The states of AL, FL, GA, KY, MS, TN, and VA.

^c The states of AR, IL, IA, and MO.

^d The states of OK and TX.

^e The states of KS, NE, ND, and SD.

^f The states of CA, CO, MT, NM, OR, and WY.

The final odds ratios and confidence intervals from the two SUDAAN models using all operations, and excluding operations with morbidity between 5 and 10% are summarized in Table 3. Based on a composite Wald F p -value <0.05 for the region variable, all region variables were included as a group in both models. The southwest region was associated with a decreased risk of being a high-morbidity herd. All dystocia categories were associated with increased odds of being a high morbidity herd in both models. Based on a composite Wald F p -value <0.05 for the confined calving variable, all confined calving categories were included as a group in both models. Calving $>70\%$ of cows and heifers in confined facilities was associated with increased odds of being a high morbidity herd. No association was found between calf-morbidity levels and herd size, regular observation of calving, specific dystocia categories such as cow dystocia, or hard dystocia (hard pull or cesarean section), or percent heifers in the herd. The p -value from the Hosmer Lemeshow goodness-of-fit statistic for the final unweighted model including all herds was 0.986 indicating excellent fit. For the model that excluded herds with morbidity risk between 5 and 10%, the Hosmer Lemeshow goodness-of-fit p -value was 0.969. There are no goodness-of-fit statistics to assess the fit of weighted models in SUDAAN.

The summary PAF for dystocia and confined calving was 0.46. The PAF for dystocia and confined calving were 0.41 (90% CI: 0.3, 0.48) and 0.11 (90% CI: 0.02, 0.16), respectively.

4. Discussion

The weighted mean herd size of herds included in the analysis was larger than the national average for beef cow–calf herds (USDA-NASS, 1997). The mean herd size represents the 23 states included in this survey, while the NASS estimate of USA mean herd size includes all 50 states. These data allow for USA population estimates of the effect of dystocia and confined calving as well as the importance of these risks through the calculation of population attributable fractions. Results of this study should be interpreted in light of the strengths and weakness inherent in an observational survey. The sample size represented here is large, and with techniques to adjust parameter estimates for sampling design and herd clustering, allows a good estimate of population effects. The data set is based, however, on producer perception and recollection — with or without records — of morbidity, management, and event variables. The potential imprecision introduced by this is dealt with in this analysis by dichotomizing the results into high- and low-morbidity herds (Losinger et al., 1998). Although there is potential imprecision in individual producer point estimates of dystocia and morbidity, this effect is limited to those herds around the 10% cutpoint by classifying herds into high and low categories. The 10% cut-off was used because it was thought to be an achievable level of morbidity for beef herds, and it is above the mean morbidity risk in this population of 5.8%. Additionally, the effect of potential imprecision was evaluated by the second logistic regression model, excluding all herds with morbidity risk between 5 and 10% similar to a previous study (Losinger et al., 1998). In the second model, herds with $\geq 10\%$ morbidity were compared to herds with $\leq 5\%$ morbidity, which is below the mean morbidity risk of this population. The parameter estimates were similar between the two models —

suggesting that imprecision in morbidity risk estimates was not influential in the model estimates.

Because of similar concerns about validity of producer-defined morbidity categories, a single morbidity risk was calculated for each herd by adding the estimates in each category and dividing by the total number of live-born calves in the herd. Additionally, although the etiologic agents associated with specific morbidities are different, the risk factors for general morbidity were hypothesized to be similar. Individual-animal morbidity data were not collected. As such, it is possible that an individual calf could be counted more than once in the producer morbidity counts. In most cases, we believe this repetition probably resulted in the recording of separate incidents of disease and may be considered as a legitimate measure of increased morbidity risk at the herd level as well as labor and drug intervention costs resulting from elevated herd morbidity risks.

The mean morbidity risk reported in this study was 5.8% (i.e., 5.8 morbidity events per 100 calves born alive). This risk was lower than in one previous report (Salman et al., 1991a) which followed calf morbidity from birth to weaning, but similar to those reported by Wittum et al. (1994a,b) who followed calf morbidity from birth to 45 days of age. The USDA Cow/calf Health and Productivity Audit (CHAPA) reported a morbidity risk of 2.9% for diarrhea and 0.6% pneumonia from birth to weaning (USDA:APHIS:VS, 1993). The mean dystocia risk for cows and heifers combined in this study population was 4% (USDA:APHIS:VS, 1997a). Similar risks were reported in other studies (Wittum et al., 1990; Salman et al., 1991a; McDermott et al., 1992). Though the heifer dystocia risk was 16.7% in the study population reported here, percent of heifers was not significantly associated with high herd-level calf morbidity. Risk for morbidity in heifer's calves might be accounted for in the dystocia variable. Alternatively, the lack of association between percent heifers and high herd-level calf morbidity may be due to the limited number of herds that calved heifers.

Variables defining regions were included in the model as a group based on a significant Wald *p*-value; only the south-central region (TX and OK) was significantly different than the southeast region (reference category) in the model. Herds in the south-central region were significantly less likely to be high-morbidity herds in both models (odds ratio=0.4). The reasons for this difference are unclear; however, environmental, management or reporting differences might exist which could account for the decreased risk.

The effects of dystocia on the neonatal calf have been extensively reviewed at the individual-animal level (Carstens, 1994; Rice, 1994). Most research has focused on calf mortality rather than morbidity. With the large sample size and use of weighted, design-adjusted analysis, this study provides population estimates of the effects (and relative importance) of dystocia and confined calving on calf morbidity at the herd level. As the dystocia risk increased in these models from one category to the next, the associated point estimate for that odds ratio also increased — although the 95% confidence intervals overlap. This is consistent with research at the individual-animal level that indicates calves experiencing dystocia are more likely to experience morbidity (Rice, 1994; Wittum et al., 1994a).

In both models, calving >70% of cows and heifers in confinement was associated with increased risk of high morbidity. This suggests a threshold level of confinement where labor inputs are exceeded or population density and environmental contamination reaches

a level where disease transmission probability increases sufficiently to sustain an outbreak. Calving in confinement not only provides the opportunity for increased observation of calving to minimize the effects of dystocia, but also increases the population density and the risk for disease transmission. As with the dystocia variables, the 95% confidence intervals for risk of confined calving percent overlap.

We examined predominant calving season as a risk for high herd morbidity based on previous work indicating increased mortality risk for winter born calves in Ontario (Ganaba et al., 1995). In this survey, predominant calving season of the herd was not associated with high herd-level calf morbidity in the univariate screening ($p>0.25$). This survey included regions with diverse climates where calving season might be expected to have variable effects; however, the interaction between predominant calving season and region was not associated with high herd-level calf morbidity ($p>0.25$).

The method used to estimate the PAF is based on the multiple-logistic model to estimate the odds ratio while controlling for confounding effects of other variables (Bruzzi et al., 1985). The summary PAF estimate of 0.46 is interpreted to mean that 46% of herds with high calf morbidity could be moved to the low-morbidity category by eliminating the effects associated with dystocia and confined calving. It would be unrealistic to eliminate all dystocia from beef herds; nonetheless, the PAF reported here serves to indicate the relative effect of dystocia on calf morbidity. The greater PAF for dystocia indicates that it is a more-important variable to focus control efforts on than is confined calving. According to Bruzzi et al. (1985), if the model variables are statistically independent and no interaction is present, then the complement of the summary attributable risk should equal the product of the complements of the separate attributable risks. In this study, the complement of the summary PAF is 0.536 and the product of the complements of the individual PAF estimates is 0.525 — suggesting independence and no interaction between dystocia and confined calving. The 90% confidence intervals calculated for these PAF estimates are only crude estimates as the methodology for calculating confidence intervals for attributable fractions from complex, weighted survey designs have not been developed (Wells et al., 1996).

5. Conclusion

The analyses reported in this study quantitate the effects of herd dystocia risk and the proportion of calvings in confined facilities on the risk for high herd morbidity. Dystocia categories were associated with increased odds of $\geq 10\%$ herd level calf morbidity. A high proportion of calvings in confinement had a moderate association with increased morbidity. Population attributable fractions indicate that effects of increased levels of dystocia are responsible for high morbidity levels in approximately 41% of high-morbidity herds.

Acknowledgements

The authors thank the NASS enumerators and state and federal statisticians for their roles in selecting and contacting this sample of beef producers and collecting the data for

this analysis. In addition, none of this would have been possible without the co-operation of all the beef producers who participated in the survey.

References

- Bruzzi, P., Green, S.B., Byer, D.P., Brinton, L.A., 1985. Estimating the population attributable risk for multiple risk factors using case-control data. *Am. J. Epidemiol.* 122, 904–914.
- Carstens, G.E., 1994. Cold thermoregulation in the newborn calf. In: Kasari, T.R., Wikse, S.E. (Eds.), *Vet. Clin. North Am.: Food Anim. Practice* 10 (1), 69–106.
- Dargatz, D.A., Hill, G.W., 1996. Analysis of survey data. *Prev. Vet. Med.* 28, 225–237.
- Ganaba, R., Bigras-Poulin, M., Belanger, D., Couture, Y., 1995. Description of cow–calf productivity in Northwestern Quebec and path models for calf mortality and growth. *Prev. Vet. Med.* 24, 31–42.
- Hosmer, D.W., Lemeshow, S., 1989. *Applied Logistic Regression*. John Wiley & Sons, New York.
- Kasari, T.R., Wikse, S.E., 1994. Perinatal mortality in beef herds. *Vet. Clin. North Am.: Food Anim. Practice* 10(1), 1–185.
- Losinger, W.C., Bush, E.J., Smith, M.A., Corso, B.A., 1998. An analysis of mortality in the grower/finisher phase of swine production in the United States. *Prev. Vet. Med.* 33, 121–145.
- McDermott, J.J., Allen, O.B., Martin, S.W., Alves, D.M., 1992. Patterns of stillbirth and dystocia in Ontario cow–calf herds. *Can. J. Vet. Res.* 56, 47–55.
- Rice, L.E., 1994. Dystocia related risk factors. In: Kasari, T.R., Wikse, S.E. (Eds.), *Vet. Clin. North Am.: Food Anim. Practise* 10 (1), 69–106.
- Salman, M.D., King, M.E., Odde, K.G., Mortimer, R.G., 1991a. Annual disease incidence in CO cow–calf herds participating in rounds 2 and 3 or the National Animal Health Monitoring System from 1986 to 1988. *JAVMA* 198, 962–967.
- Salman, M.D., King, M.E., Odde, K.G., Mortimer, R.G., 1991b. Annual costs associated with disease incidence and prevention in CO cow–calf herds participating in rounds 2 and 3 or the National Animal Health Monitoring System from 1986 to 1988. *JAVMA* 198, 968–973.
- SAS Institute, 1990. *SAS/STAT User's Guide*. SAS Institute, Cary, NC.
- Shah, B.V., Barnwell, B.G., Bieler, G.S., 1996. *SUDAAN User's Manual*, Release 7.0. Research Triangle Institute, Research Triangle Park, NC.
- USDA:APHIS:VS, 1993. Part I: Beef Cow/calf herd management practices in the United States. Centers for Epidemiology and Animal Health, Ft. Collins, CO, N130.893.
- USDA:APHIS:VS, 1997a. Part I: Reference of 1997 Beef Cow–Calf Management Practices. Centers for Epidemiology and Animal Health, Ft. Collins, CO, N233.697.
- USDA:APHIS:VS, 1997b. Part II: Reference of 1997 Beef Cow–Calf Health and Health Management Practices. Centers for Epidemiology and Animal Health, Ft. Collins, CO, N238.797.
- USDA:NASS, 1997. *Agricultural Statistics*. Washington, DC (Tables 7–21).
- Wells, S.J., Dargatz, D.A., Ott, S.L., 1996. Factors associated with mortality to 21 days of life in dairy heifers in the United States. *Prev. Vet. Med.* 29, 9–19.
- Wittum, T.E., Curtis, C.R., Salman, M.D., King, M.E., Odde, K.G., Mortimer, R.G., 1990. Management practices and their association with reproductive health and performance in Colorado beef herds. *J. Anim. Sci.* 68, 2642–2649.
- Wittum, T.E., Perino, L.J., 1995. Passive immune status at postpartum hour 24 and long-term health and performance of calves. *Am. J. Vet. Res.* 56, 1149–1154.
- Wittum, T.E., Salman, M.D., King, M.E., Mortimer, R.G., Odde, K.G., Morris, D.L., 1994a. Individual animal and maternal risk factors for morbidity and mortality of neonatal beef calves in Colorado. *Prev. Vet. Med.* 19, 1–13.
- Wittum, T.E., Salman, M.D., King, M.E., Mortimer, R.G., Odde, K.G., Morris, D.L., 1994b. The influence of neonatal health on weaning weight of Colorado, USA beef calves. *Prev. Vet. Med.* 19, 15–25.